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COMPLETE SPECIFICATION.

Improvements relating to the Protection of Stored Combustibles against Fire.

I, WALTER JOHN WILLENBORG, of 36, Clifton Terrace, Weehawken, State of New Jersey, United States of America, Citizen of the United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the protection of stored combustibles against fire by a protective atmosphere, and to an economic maintenance of a safe standard of inertness in such an atmosphere. The protective atmosphere is tested by thermal conductivity measurements and conditioned according to the results of such tests. Hence the invention consists in maintaining a protective inert atmosphere by measuring the thermal conductivity thereof and controlling automatically by the results of such measurement the injection of an inert gas, so that the character of inertness of the protective atmosphere is substantially preserved. In addition the invention may provide means supplying inert gas for restoring normal pressure conditions when the protective atmosphere is rarefied below a normal pressure range, as well as the usual relief of pressure when the protective atmosphere acquires a pressure exceeding such normal pressure range.

The storing and handling of combustibles presents a difficult problem, particularly in the case of such combustibles which readily give off inflammable gases; it is the object of this invention to provide protective means for the spaces in which combustibles are kept.

An important object of my invention is to provide and maintain, in spaces in which combustibles are kept, an atmosphere in which such combustibles, or gases given off thereby, cannot be inflamed or burned.

Another object is to devise means by which the so-called "inert" atmosphere in spaces which serve for the storage of combustibles is kept substantially at atmospheric pressure, so that the walls of said spaces are not exposed to excessive strains. Giving to the walls of such spaces sufficient strength to withstand the pressure of the atmosphere on the outside, in case the atmosphere in said spaces is rarified, or to withstand an excessive pressure of the "inert" gases contained therein would represent a considerable economical burden, particularly because such spaces are frequently very large.

Another important reason for preserving the "inert" atmosphere in such spaces at a pressure substantially equal to that of the atmosphere surrounding said spaces is the object of preventing the leakage of the "inert" gases contained therein through cracks or openings in the walls making up said spaces, or, to prevent the diffusion of the outside air through such cracks or openings into the "inert" atmosphere which is maintained on the inside of such spaces.

A further object of this invention is to maintain the "inert" atmosphere in a space, in which combustibles are contained, at a standard of safety which experience has proven to offer a fully satisfactory protection and automatically to raise said standard of safety in case the requirements of protection are increased, when inflammable gases are given off by the combustibles in said spaces.

It is another object of my invention to provide compensation for the fluctuation of the amount of "inert" gases contained at substantially atmospheric pressure in such spaces, such fluctuation being caused by an increase or decrease of temperature.

In connection with the storage of combustibles conveying means and machinery for handling such combustible materials are provided for and should be protected in the same manner as the spaces in which the combustibles are stored; in fact a greater degree of protection must frequently be accorded to the spaces where such means and machinery are operated, because mechanical friction and electric sparks, which are difficult to avoid in the operation of such means and machinery, must be protected to prevent ignition and explosion of the surrounding atmosphere. I have devised a regulation for the atmosphere in the spaces in which such means and machinery are kept, which affords a

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protection against such ignition or explosion and at the same time permits the entrance of a person into the respective spaces for the purpose of manually operating such means or machinery in the case of an emergency.

Another, important object of my invention is to provide for the protection of the inside of the tanks of a tanker, which are known to corrode and deteriorate at an extraordinary rate under the combined and alternating influences of salt water, air, oil and oil-vapors. Such deterioration is effectively prevented by my invention in which the atmosphere in the tanks is largely rendered inert.

In view of those and other objects I have developed the method and means described below, and I have exemplarily chosen for an illustration of my invention a prominent field of its application, which are tankers used for the oversea transportation of inflammable liquids, such as oil, petroleum or gasoline. Such tankers and the means which I use in the application of my protection to such tankers are illustrated in the accompanying drawings, in which,

Figure 1 is a side elevation of part of a tanker.

Figure 2 is a corresponding plan view of the tanker.

Figure 3 shows a diagrammatic top view of the arrangement of pipes, blowers and control means in the shaft.

Figure 4 is a corresponding sectional side elevation of part of the shaft.

Figure 5 is a part sectional side elevation of the forepart of a vessel showing a modification of my invention.

Figure 6 shows a diagrammatic view of the vapor indicator and the apparatus controlled thereby.

Figure 7 shows a side view partly in section of the breathing means.

Similar numerals refer to similar parts throughout the various views.

The tanker shown in Figures 1 and 2 is laid out along the lines of present day practice of constructing vessels of this type. The engine and boiler rooms are arranged in the stern of the vessel and the power plant comprises a generator which supplies steam or electricity for the operation of the motive parts, primarily pumps, used in connection with my improvements; the bow is used for freight, and quarters for the crew, whereas the tanks containing the liquid cargo are arranged therebetween and are ordinarily separated from the fore and aft parts of the vessel by protective coffers. Two vertical shafts 13 and 14, which are normally open at their upper ends, extend down from the main deck to substantially the keel; in their lower ends 15 are arranged the oil pump which serve to pump the oil out of the vessel. Two pairs of main tanks 16 and 17 are arranged aft each of the shafts 13 and 14 and correspondingly two pairs of tanks 18 and 19 are arranged fore thereof. Alongside of the tanks 16, 17, 18 and 19 are indicated the wing tanks 10 which may be protected by my improvements in a manner corresponding to the hereinafter described protection of the first-mentioned tanks.

The various tanks are ordinarily filled with oil or gasoline 12, a small clearance being allowed between the surface of the liquid and the top walls of said tanks, which are represented by the main deck. These clearances allow for the expansion and contraction of the liquid under different temperatures; the variations in temperatures to which the vessel is exposed are at times considerable; these temperatures change between day and night time, the main deck being heated up during the day owing to full exposure to the rays of the sun.

The variation in temperature of the liquid contained in the tanks would cause considerable fluctuation of the pressure of the gas contained in the tank above the liquid, if the tanks were hermetically sealed, and the walls of the tanks would thereby be exposed to dangerously high and low pressures. For this reason so-called breathers are ordinarily provided, which, through a trap-like arrangement, connect the gas filled space above the liquid in the tank to the outside and through which the pressures above the liquids in the tanks may be balanced against the atmosphere. Through such breathers air is taken in when, at sunset, the contracting contents of the tanks tend to create a vacuum thereabove; whereas gas is driven out through the breathers, when the temperature rises in the morning.

In my invention the unidirectional valves 20 take the place of the breathers. They permit the excess pressure of gas above the liquid in the tanks to be relieved therethrough, but they do not allow air from the outside to enter into the space above the tanks at night, when the temperature drops and a vacuum is created above the liquid, but I provide in that case other means for restoring the low gas pressure above the liquid to a normal pressure, which is slightly above atmospheric pressure.

The unidirectional valves may be constructed according to the simple principles of a safety valve; they may take the shapes of traps, the liquid in which allows the passage of gas therethrough in one but

not in the other direction or they may take the shape of one of the many devices which provide for unidirectional sensitive gas pressure control. To the unidirectional valves are connected the pipe lines 21 extending to the sides of the ship and their outlets 22 issue overboard, below the level of the main deck.

A detailed illustration of a particular modification of the breathing apparatus is shown in Figure 7. Here the check valve 20 takes the shape of a pressure regulating valve of the type known to those acquainted with the art of valve gears. The checking operation in the valve body is brought about by the plunger 101 which operatively connects a diaphragm in the diaphragm in the diaphragm chamber 102 to the shut off means in the valve body proper. The valve connects by means of the pipe 103 to the space above the liquid in the tank and an auxiliary pipe 104 bypasses a small amount of the gas coming from the tank into the diaphragm chamber. In the diaphragm chamber the diaphragm is raised and lowered according to a higher or lower drop of pressure between the gas above the liquid in the tanks and atmospheric pressure. From the valve 20 the pipe 21 connects to a flash-arrester 105. The flash-arrester consists of an enlarged chamber 106 and a screen 107 which extends across the whole horizontal extent of said chamber 106. Flash-arresters of this kind are used in the line through which surplus gas is released from the pump room, as well as throughout the apparatus of my invention wherever pipe lines issuing from one or the other tank are merged or are connected to a common header. If for any unforeseeable reason an inflammable gas mixture is contained in one or more of the tanks, such flash-arresters prevent the propagation of an explosion, which may occur in one of said tanks, to the other tanks. Below the flash-arrester, above the outlet of the breather line, the pipe shows another enlarged chamber 108 in which a hollow ball 109 is supported, from below, by brackets 110. Chamber 108 is of such size as to allow a free passage of the gases breathed out from the tanks around said ball 109. The contracted lower end of the pipe prevents splashing of water thereinto and the ball 109 is buoyed and blocks the neck 111 of chamber 108, when the lower end of the breather pipe line is submerged under water in a rough sea.

Near the center of the body arises above the main deck an "inert" gas generating plant 23 in which, by means of an internal combustion engine 24, gases are produced which are commonly termed "inert" gases. These "inert" gases are the exhaust gases of the engine 24 and are termed "inert" gases because they are non-oxidizing, inasmuch as they prevent the combustion of inflammable materials therein, unless such inflammable materials contain the oxygen required for their combustion. The exhaust gases of the engines 24 are purified and cleansed in scrubbers 25 and then they are stored in high pressure tanks 26. These high pressure tanks are connected by pipe lines 28 to a reducing valve board 27 from where pipe lines 29 connect into the shafts 13 and 14. The reducing valves are set to maintain the gas in pipe lines 29 at a pressure which assures a free flow of said gases to the points of use of such gas, when required. The gasoline for the operation of engines 24 is supplied from an auxiliary gasoline tank 30. This gasoline tank and the pipe line 31 connecting said tank to the engines are protected and jacketed with "inert" gas mantels according to the present-day practice of protecting inflammable liquids.

In the shafts 13 and 14 I provide decks 32 above the pump spaces 15. The pumps in these spaces may be arranged for operation from above this deck 32 and can be observed through openings sealed by heavy glass covers 33. These pump rooms are filled with an "inert" atmosphere, means for maintaining such an atmosphere being more specifically discussed below. At times, when it becomes necessary to enter this chamber, air is admitted, so that the breathing of a person entering the pump room is not impaired; at the same time an explosion-proof condition of the atmosphere in the pump room may be maintained, it being known that the oxygen in a room may be reduced to such an extent, that it will not permit ignition of inflammable materials, said atmosphere not causing to a person entering thereinto any serious discomfort except a slight shortness of breath.

On deck 32 in the pump room I install the apparatus by which I protect the inflammable liquids contained in the various tanks 16, 17, 18 and 19. The equipment in each of the shafts 13 and 14, comprises four blowers 34, 35, 36 and 37 and a smaller blower 38. These blowers respectively discharge through pipe lines 39, 40, 41, 42 and 43 into the pairs of tanks 16, 17, 18 and 19 and into the pump rooms 15, the pipe line 43 issuing into the pump rooms 15 discharging to a high point in said pump room. Each one of the discharge lines 39, 40, 41 and 42 is branched off at its end into lines 44 and 45 which issue into the respective pairs of port and starboard tanks below the main deck and above the top level of the liquid.

The suction lines 46, 47, 48, 49 and 50 connect, as return lines, the tanks 16, 17, 18 and 19 and the pump rooms 15 to the blowers 34, 35, 36, 37 and 38. In the manner of the branches 44 and 45 issuing from the discharge lines 39, 40, 41, and 42 into the various tanks 16, 17, 18 and 19, the suction lines 46, 47, 48 and 49 are branched off at their ends by lines 51 and 52. The pipe lines 51 and 52 issue upon the opposite ends of the spaces above the liquids in each of the port and starboard tanks.

The discharge lines are provided with check valves 53 at points near the blower end; ahead of these valves, small pipe lines 54 branch off and lead to the vapor indicators 55. Behind the check valves the pipe lines 56 issue into the discharge lines. These pipe lines 56 connect to the solenoidal valves 57 which in turn connect to a manifold 58 to which " inert " gas reduced to a predetermined pressure is supplied from the reducing valve board 27 of the " inert " gas generating plant by pipe line 29. The solenoidal valves connect to the manifold 58 by the pipe lines 59, 60, 61, 62 and 63, which, respectively, belong to the systems of the blowers 38, 34, 37, 36, and 35.

The operation of the vapor indicators and of the solenoidal valves may best be seen from the diagram of Figure 6; an unbalanced Wheatstone Bridge 64 is connected by means of wires 65 and 66 across the source 67 of a constant E.M.F. One pair of arms of the bridge are formed by the fixed resistances 68 and 69, whereas the other pair of arms contain the resistance wires of the thermal conductivity units 70 and 71. The galvanometer 72 is connected across the bridge as an indicating instrument by means of the wires 73 and 74. Thermal conductivity unit 70 is bridged by a suitable resistance wire and it contains a comparison gas, whereas the thermal conductivity unit 71 which is equipped with a similar resistance wire is connected at the inlet 75 to the small pipe line 54 through which gas is supplied for analysis from the respective blower.

The galvanometer is empirically calibrated, showing a scale from zero to 100 which may be defined as a percentage scale for " inertness " of the tested gas. The divisions are arranged in such a manner that a deflection to the 50 point of the scale is registered by the galvanometer when air,—to which so much inert gas is admixed that it does not sustain combustion—passes through the conductivity unit 71, whereas the 100 point of the scale is registered, when the best possible " inert " gas produced by the generating plant 23 is introduced in the thermal conductivity unit 71.

Exemplarily I choose the calibration point 50 of the scale for the quality which is to be maintained in the gas above the liquid in the tanks. I exemplarily allow 15% upward and downward marginal limits for that standard; therefore I have provided means that a supply of substantially fully " inert " gas which has been delivered by the generating plant is admitted through the pipe line 56 into the discharge of the blower, when the " inertness " indicator registers 35, but I shut off this supply of " inert " gas when the " inertness " is indicated to have risen to 65%. Simple means to bring about such a control of the supply of " inert " gas by means of the vapor indicator are shown in Figure 6; the hand 76 of the galvanometer 72 carries a brush 77 near its pointed end which is adapted to contact electrically with the segments 78 and 79, when either an " inertness " from zero to 35% or from 65% to 100% is registered. Electricity is supplied to the hand by means of wire 80 and it flows from the galvanometer through wires 81 and 82 to relays 83 and 84, when the brush 77 on hand 76 contacts with the segments 78 and 79, respectively. A return wire 85 closes the electric circuit and it also supplies current to the polarized magnet lever 86, which will swing to the right or to the left according to whether relay 83 or relay 84 is excited.

Whereas the various pieces of electrical apparatus are shown to be supplied with current from a common source 67, they may of course be supplied from different sources of current, each one of which is particularly suited for the respective current requirements; or the various electrical devices such as the analysis units, the solenoidal valves, the relays, and the apparatus used collaterally in the galvanometer operation may be floated on the line of the ships electrical power supply.

The diagrammatic drawing of Figure 6 illustrates the principle upon which the vapor indicator controls the " inert " gas supply. In a practical application the hand 76 of the galvanometer is of course not used for carrying currents, nor do I ordinarily use a sliding contact, like brush 77; for closing the relay circuits. The present art of delicate electrical registering and contact-closing instruments offer a vast range of apparatus from which I may choose the one best adapted for the problems of a particular installation. The circuit closing contact does not have to be brought about directly by the hand 76, but the present state of the art

offers many instruments in which such a contact is indirectly brought about and instruments in which periodically, at short and regular intervals of time, mechanical means automatically feel out or test the position of a pointer and accordingly close or open relay circuits, and which may readily be substituted for the apparatus diagrammatically shown in the drawings.

The lever 86 is retained in its positions of attraction to one or the other of the relays by the wedge-shaped nose extending from an upwardly tensioned catch 87, said wedge-shaped nose engaging the right or left side of the lower pointed end of the lever 86 in the extreme positions of deflection of said lever. When the lever 86 is attracted by relay 84, it closes the circuit 94 of the solenoidal valve 57, at the point of contact 88, which in the drawing is connected across the source 67 of electric power. The solenoidal valve 57 is normally open, so that it allows " inert " gas to be supplied from the generating plant to the discharge lines of the respective blowers, when the solenoid is not excited.

The lever 86 being swung to the right in the drawing and the solenoid circuit 94 therefore being open, the solenoidal valve is open. But if the percentage of " inertness " registered by the galvanometer rises from 38 to 65, contact of brush 77 with the segment 79 is brought about, the relay 84 is energized, lever 86 is thrown to the left, into contact with contact point 88, the solenoid contact 94 is closed and the supply of " inert " gas from the reducing valve board of the generating plant to the corresponding discharge line is shut off.

If the degree of " inertness " of the gas circulating through the respective blower decreases slowly until it reaches the low safe margin of 35%, the brush 77 will contact with segment 78, the solenoid circuit is opened and the solenoidal valve opens, the degree of " inertness " of the gas which moves from the respective blower through the respective discharge line being increased by the supply of fully " inert " gas from the generating plant. The galvanometer will consecutively register a higher degree of " inertness " until the upper margin of 65% has been reached again, when the supply through the solenoid valve is shut off.

An alarm 90 is connected in parallel with relay 83. It may be taken out of the circuit by opening switch 91. When switch 91 is closed the alarm will be actuated whenever the " inertness " of the gas circulating through the respective blower is below the safe lower margin of 35%.

The arrangement of Figure 5 shows the " inert " gas generating plant located in an alternative position near the bow of the boat. From the reducing board 27 of the generating plant the " inert " gas passes in this modification to a main pipe line 92. Branches 95 of that pipe line run to each of the main tanks and to the pump room and are respectively controlled by the respective solenoidal valve 57. Small motor driven pumps 93 are arranged near the undirectional breather check valves 20 and they continuously supply a small amount of the gas to the vapor indicators 55. Wires connecting the vapor indicator 55 to the solenoidal valves 57 form part of the solenoid circuits 94.

Whereas any kind of an " inert " gas may be used to create a safe atmosphere in the various spaces in which combustibles are stored or handled, the most economical gas used today for such purposes is the properly cleaned exhaust gas of an internal combustion engine. The arrangement of a generating plant for such gases has been described by me in my English patent No. 352,006, dated February 19, 1929, entitled " Improvements in or relating to Means for Producing and Storing Non-Oxidizing Gases ", and plants of this kind are indicated at 23 in Figures 1 and 2 near midship and in Figure 5 near the bow of a boat. Such a plant produces an exhaust gas, cleans it, tests it and automatically stores it in high pressure tanks 26. The high pressure tanks issue upon a reducing valve board 27. The gas flows from the high pressure tank through the valves mounted on that board, and from there, at a reduced pressure,—when the line pressure, at the point of use, drops below a predetermined pressure standard, to which the reducing valves are set,—into the main distributing lines 29.

In the above cited prior patent it has been stated that any reliable apparatus serving for the determination of the carbon dioxide contents in a certain atmosphere may be satisfactory for checking the quality of the " inert " gas produced in the generating plant. The thermal-conductivity measurements described in this invention are, however, particularly adapted to the determination of the inertness of such an " inert " gas. Such measurements are performed in the vapor indicators 55 which serve to check the quality of the gases in the spaces above the liquids in the tanks as well as the quality of the gas in the pump rooms 15. I illustrate in Figure 6 of my drawings the apparatus comprised in said indicators, which seems particularly adapted for the purpose of protecting spaces to which I have referred in my introduction. In

addition to reacting to and registering the carbon dioxide contents of the atmosphere to be tested, this apparatus is also influenced by the inflammable gases which are apt to raise from the oil or gasoline stored in the various tanks of a tanker.

In observing the thermal conductivity of gases the value of the conductivity of a gas is compared with air and the observed or computed ratio is termed the factor of thermal conductivity of a gas. The gases primarily affecting the thermal conductivity measurements in connection with the protection of tanks in which hydrocarbons are stored are carbon dioxide, hydrogen and, to a smaller degree, hydrocarbon vapors and nitrogen. The thermal conductivity factor of carbon dioxide is comparatively low and I have found that the protective quality of an exhaust gas is the greater, the larger the percentage of carbon dioxide contained therein. Since carbon dioxide primarily influences the thermal conductivity test of an exhaust gas, the actual percentage of carbon dioxide in an exhaust gas can be substantially directly observed and registered on a galvanometer by means of a Wheatstone Bridge arrangement.

The comparison gas is accommodated in the thermal conductivity unit 70, whereas the gas to be tested passes through the thermal conductivity unit 71. The inlet 75 of the latter is therefore connected to one of the small pipe lines 54 which issue from the discharge lines of the tanks and of the pump rooms.

The heat imparted to the wire in unit 70 by the current passing therethrough is uniformly conducted away by the comparison gas contained in said unit, said gas remaining the same according to the practice of thermal conductivity measurements. In the other unit 71 a change of the thermal conductivity of the gas passing therethrough will change the rate at which said gas conducts away the heat imparted to the wire extended therethrough by the current passing through the respective branch of the Wheatstone Bridge. This involves corresponding temperature changes in the wire, and, in turn, a change of the electric resistance thereof and of the current passing therethrough. Since these current variations are definitely related to the thermal conductivity changes of the gas passing through unit 71, the galvanometer 72 reacts upon those currents, and registers in predetermined relation to the thermal conductivity of the tested gas.

In the modification of Figure 5 each thermal conductivity unit 71 of each vapor indicator 55 is connected to a small pump 93 which withdraws a small sample of the gas contained above the inflammable liquid in the respective tank, from a corner opposite the corner at which the supply of "inert" gas issues into said space through the respective pipe 95. Whereas in the testing apparatus of my prior invention the testing of the exhaust gases only had to be considered and the dilution of said gases with air was the largely determining factor for the percentage of carbon dioxide observed, in this new application of a thermal conductivity unit for determining the quality of gases withdrawn from the space above hydrocarbons the gases volatilized from the hydrocarbons must also be considered in the reading registered, and hydrogen and other gases given off by inflammable liquids indeed exert a great influence upon the thermal conductivity of the atmosphere they are contained in. Hydrogen has a high factor of thermal conductivity and its influence upon the reading observed is directly opposed to the deflection caused by carbon dioxide. The scale of the galvanometer 72 being empirically divided to register the positively inert quality of an atmosphere from the centre of the scale which would correspond to the thermal conductivity of air made inert by an exhaust gas to the point of preventing free combustion, to a maximum "inertness" which would correspond to the highest possible carbon dioxide contents ordinarily observed in exhaust gases, the introduction of hydrogen or of gases which have similar thermal conductivity factors will tend to cause the deflection of the needle 76 in counter-clockwise direction, so that the galvanometer will register less "inertness" in an "inert" atmosphere, as soon as hydrogen or similar inflammable gases are introduced into said atmosphere. The galvanometer is arranged to operate the collateral apparatus so as to preserve an average "inertness" of 50%. Assuming that there is an average "inertness" of 50%, the "inertness" registered will fall below the "50" calibration as soon as inflammable gases enter upon the thermal conductivity unit as ingredients of a sample "inert" atmosphere. Consequently the collateral apparatus will function now, injecting "inert" gas into the atmosphere, in such a manner that the actual percentage of "inert" gases will be though the galvanometer needle only returns to the safe range around the 50 point of the scale. Therefor the galvanometer does not show inertness in terms of percentage of inert gases present, but a true inertness, i.e., the former offset by the presence of inflammable gases. This is a very valuable characteristic of the exemplarily shown arrangement of my

invention, the safety being automatically increased when inflammable gases are present.

The solenoidal valve 57 is shown enlarged in Figure 6 and the flow of gas pressure is indicated to take place from the right to the left. When the solenoid is excited the stem of the valve is lifted and the port is closed, the valve seating therein from below, so that the supply of "inert" gas from the reducing valves, to the right, is shut off from the spaces above the liquids or from the pump rooms, to the left of said valve. The force with which the solenoid holds or retains the valve in its seat can be adjusted so that it is readily overcome by a certain drop of the pressure from the right to the left in said valve. This allows the solenoidal valve to be also used as a check valve. "inert" gas being admitted to the spaces above the liquids in the tanks, or to the gases circulating therethrough when the pressure drops below a certain fixed value. In a practical application of my invention I preferably use pressure control means which act independently of the quality-controlling solenoidal valves. Such means are not indicated in Figure 3, not to obscure the principle of the invention shown. But in Figure 4 a check or pressure regulating valve 120 is shown inserted between the point 97 of line 40 and the line 63 connecting the corresponding solenoidal valve to the manifold 58 and correspondingly the pipes 59, 60, 61 and 62 may be connected by check or pressure regulating valves to a point 100 on pipe line 43, 96 on line 39, 99 on line 42, and 98 on line 41, respectively.

The check valves 20 of Figure 5 function in substantially the manner of the valve 20 shown in Figure 7. From these valves pipe lines 21 connect to the sides of the ship and for a certain distance downward, overboard, so that the gas "breathed out" through the valves 20 when the pressure in the tanks rises above a predetermined pressure in excess of normal atmospheric pressure. is removed from the deck of the ship. Owing to its heaviness such gas will drop on to the water alongside of the ship and it therefore will not inconvenience the crew of the ship moving about on the deck. This feature is of particular importance when the ship is anchored in a harbor and when there is substantially no wind to take away from the deck of the ship gases which may prove to be annoying.

The small pumps 93 of Figure 5 drive samples of the gas contained in the tanks above the inflammable liquid, and gases contained in the pump rooms near the top thereof, into the vapor indicators 55 where their quality of inertness is registered. According to the quality registered, the solenoid circuits of the solenoidal valves 57, to which the impulses of closing and opening the relay circuits by means of the contactors 77 are transmitted through the wires 94, will be operated. If the quality of the gas recorded is of insufficient safety, the supply of gas from the reducing valve board 27 is supplied through the solenoidal valves into the spaces above the inflammable liquids or into the pump rooms and such a supplying of new "inert" gas will continue until the vapor indicators 55 again registers a high degree of safety in the atmosphere in the respective spaces. The pressure of the gas supplied from the reducing valve board slightly exceeds the pressure normally preserved in the spaces above the inflammable liquids and in the pump rooms and the valves 20 are set to release at a pressure between that of the gas supplied from the reducing valve board and atmospheric pressure. The flow of "inert" gas through the pipes 95 into the various spaces will therefore not be prevented by a building up of pressure in the respective spaces, but the gas of inferior quality will be "breathed out" of the spaces above the inflammable liquids at the opposite ends thereof, until a safe standard of "inertness" has been reached in said spaces and the supply of new "inert" gas is shut off by the solenoidal valves 57.

If the pressure in the spaces above the liquids rises above the pressure normally to be maintained therein, due to expansion on account of the rise in the temperature of said gas, said surplus pressure is "breathed out" automatically through the valves 20. When the pressure in said spaces drops below the normal pressure, a new supply of "inert" gas is automatically sucked in through the solenoid valves in accordance with the action described described above, or it enters through a check valve arranged in parallel with each solenoidal valve 57. The releasing of surplus pressure from the pump rooms is not indicated in the drawing by check valves, but such releasing may take place through openings around the glazed port holes 33 or through other crevices and cracks. If such releasing should operate reversedly, sucking air into said room, the "inert" standard of safety of the atmosphere would automatically be restored since the inferior quality of the gas, as sampled in the vapor indicator 55, would bring about a supply of new "inert" gas to the pump room from the reducing valve board. As an extreme measure of safety I may of course provide check valves on the pump rooms, as I have shown them in connection with the spaces above the

inflammable liquids in the tanks. But such a measure will ordinarily not be necessary, because the gas in the pump room is not exposed to the same amount of expansion and contraction due to temperature differences which occurs in the spaces above the inflammable liquids in the tanks.

Maintaining the gas in a tank above an inflammable liquid at a fixed degree of inertness, instead of providing a fully "inert" zone therein and of completely replacing said zone whenever it might not be of such "inert" quality as to provide full protection, has the great advantage of continuous safety. It is also important from an economical point of view, because normally a very limited supply of "inert" gas is required to maintain the quality of the protecting zone. The necessity of introducing additional gas arises in my improvements primarily, when a replacement of a volume of gas, which has been "breathed out" on account of expansion, has to be made.

The system of Figure 5 requires however the release of a certain amount of the atmosphere contained above the inflammable liquid, when safe "inertness" is to be reimparted to said atmosphere. The gas thus released may also contain vapors of the inflammable liquid and the inflammable liquid will automatically give off additional amounts of vapors until a normal saturation of the newly introduced "inert" gas has been attained. A part of the most valuable ingredients of the inflammable liquid, i.e., the parts which ordinarily have the highest flash-point, are thereby removed from the inflammable liquid.

The quality of the inflammable liquid is thus impaired and I have succeeded in improving still further upon the system of Figure 5, by the system of Figures 1, 2, 3 and 4, in which substantially the same gas makes up the atmosphere above the inflammable liquids in the tanks, said gas being continuously circulated and restored to a predetermined "inert" quality during such circulation. In the drawings I show a central point at which the testing, controlling and circulating apparatus is located, i.e., in the shafts 13 and 14, above decks 32. Of course this arrangement and location of the apparatus may be modified in adaptation to the vessel or storage means, in connection with which it is used. The choice of the number of individual circulating systems shown has also been arbitrary; in the same manner in which I provide one individual circulating system for a pair of adjoining tanks, and in the manner in which I apply the circulating system to two adjoining tanks in a parallel arrangement, I may also use one system for a smaller or greater number of tanks and may connect the system to said tanks in a series arrangement. Likewise the protection provided for the tanks located along a longitudinal center line of the vessel may be extended to the wing tanks 10.

Although the description of the apparatus, as given above, explains many parts of the apparatus of Figures 1, 2, 3 and 4, I describe in the following the circuit of one circulating system, to ascertain the understanding of my invention: The pump 35 continuously withdraws the atmosphere contained in the pair of tanks 17 by means of the branches 51 and 52 of pipe line 47; at the discharge end of pump 35 a sample of the gas is by-passed through the small pipe line 54 at a pressure which may be largely controlled by dimensioning the conductors. Check valve 53 prevents a flow of the newly introduced gas in a direction opposite to that in which circulation is caused by the pump. The small pipe line 54 introduces the by-passed gas into the thermal conductivity unit 71 and the quality of the gas thus tested, as compared with the comparison gas in thermal conductivity unit 70, is registered by the galvanometer 72. The electrical parts of Figure 6 operatively connect the galvanometer 72 to the solenoidal valve 57, which controls the supply of "inert" gas from manifold 58 through pipe lines 63 and 56 into the discharge line 40 of pump 55. The gas in pipe line 40 together with the gas which thus is mixed therewith, is circulated back to the pair of tanks 17 and distributed thereinto by means of the branches 44 and 45 of the pipe line 40.

When the pressure of the gas in tank 17 above the inflammable liquids contained therein drops owing to a temperature drop, the valve 120 between the point 97 of line 40 and the line 63 operates, or the solenoidal valve 57 connecting pipe line 63 to the pipe line 56 functions as a check valve, as described above, and a supply of "inert" gas sufficient to restore atmospheric pressure in the tanks 17 passes therethrough; when such gas pressure rises above atmospheric pressure the check valve 20 allows "breathing out" of the gas, overboard, until substantially atmospheric pressure is restored in the tank 17. Of course the gas "breathed out" of the tanks may be stored in gasometers or pressure tanks, and recirculated when pressure conditions in the storage spaces warrant it.

The use of a circulating system of gas in connection with my invention brings about a great economy in the use of

" inert " gases and I therefore am in a position to provide comparatively small " inert " gas generating plants in connection with large vessels. Such smaller gas generating plants may not have a capacity sufficient to supply all the " inert " gas which may be required to fill up the complete tanks with " inert " gas, when said tanks are emptied at the point of destination. Under those circumstances it is advisable to provide on shore storage tanks or gasometers filled with " inert " gas, which supply the bulk of the amount of " inert " gas required when the vessel is unloaded. The vapor indicators on the vessel may function as protective means when " inert " gas is admitted to the tanks from the gasometers arranged along the shore of the harbor. Insufficiency of quality of the gas supplied from shore or leakage of the supply line and connections will be indicated on the respective galvanometer and an alarm is given by the respective alarm 90, for as long a period of time as the quality of the gases in the respective tank is below a standard of 35%. The alarms 90 may of course also be used during the ordinary operation of my invention to warn the crew that the quality of the atmosphere in the respective tanks is too low.

One particular modification of the apparatus is, under certain circumstances, of particular value for obtaining a high degree of safety in protecting combustibles. My thermal conductivity method may be combined with a carbon dioxide analyzer, the two kinds of tests being carried on alongside of each other, one serving to measure the general quality of the atmosphere above the combustibles and registering therefor, generally, the degree of danger of the mixed gases, the other test registering the quality of inertness, only, of the atmosphere, without consideration of the inflammable gases which are contained therein. Such compounding of tests and corresponding modification of the operation of the control valve suggests itself in particular for spaces in which the inertness cannot be carried to an extreme limit of safety but where the occasional necessity of the entrance of an operator has to be considered.

Such an arrangement could for instance be applied to the pump rooms, the compounded registering means allow, differentially, a determination of the inflammable gases present and under certain circumstances it may be advisable for the operator to flush out the atmosphere in a pump room, the atmosphere containing inflammable and " inert " gases being carried overboard, before he enters such pump room.

It is also readily understood that the calibration of the registering instrument and the degree of safety which is maintained according to the spacing of the electrical contactors upon the dial, as shown, is exemplary, only, and under varying conditions a higher or lower standard of safety may be adopted.

Although I have shown and described several specific forms of embodiment of my invention in detail, yet I do not wish to be limited thereby except as the state of the art and the appended claims may require, for a large range of modifications and changes suggest themselves to the engineer and designer applying my invention to problems of protecting combustibles, without thereby bringing about a departure from the spirit and scope of my invention.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A method of maintaining a protective inert atmosphere consisting in measuring the thermal conductivity thereof and controlling automatically by the results of said measurement the injection of an inert gas. so that the character of inertness of said protective atmosphere is substantially preserved.

2. A method according to the preceding claim applied to an atmosphere containing the inflammable vapors of liquids protected thereby, the said vapors changing the thermal conductivity measurements and the injection of the inert gas being effected accordingly.

3. A method according to either of the preceding claims, in which the testing is continuous.

4. A method according to claims 1, 2 or 3, in which the thermal conductivity measurements are calibrated to a standard requiring the presence of more inert gas in a protective atmosphere when inflammable gases are contained therein.

5. Means for carrying out the methods according to any of the preceding claims, comprising an enclosure in which said protective atmosphere is contained, a conduit circuit connected with said enclosure, a blower circulating said atmosphere through said circuit, means connecting with said circuit for testing the thermal-conductivity of the atmosphere circulated through said circuit, a supply of inert gas, means for injecting gas from said supply into said circuit, and means operatively connected with said testing means and controlling the injection of said inert gas into said circuit.

6. In combination with the means of claim 5, a pressure relief valve through which gas is released from said enclosure when said atmosphere is compressed above a normal pressure range, and a check valve supplying inert gas to said enclosure when said atmosphere is rarefied below said range.

7. The means according to claims 5 or 6, in which the thermal-conductivity measurements are calibrated to a safety range compensatory to higher inflammability due to the presence of inflammable gases in said atmosphere.

Dated this 13th day of January, 1931.

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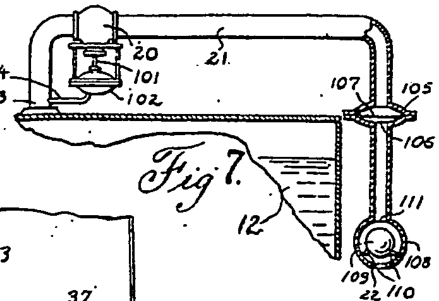


Fig 7.

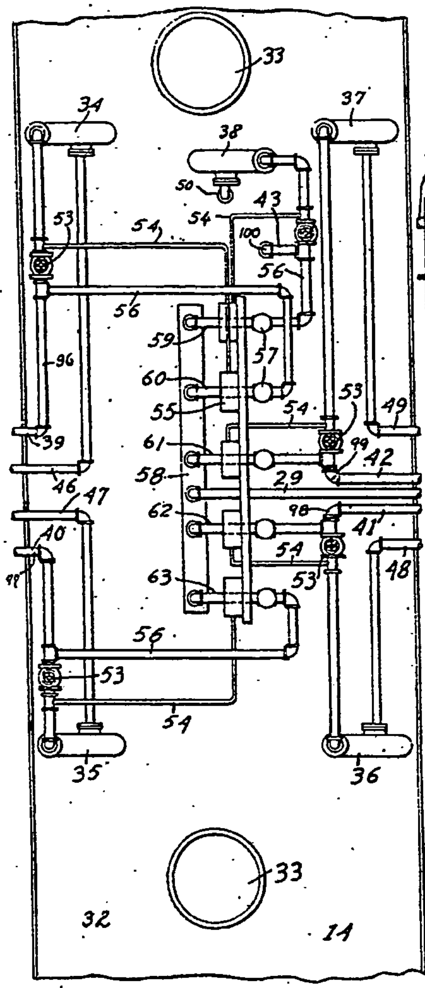
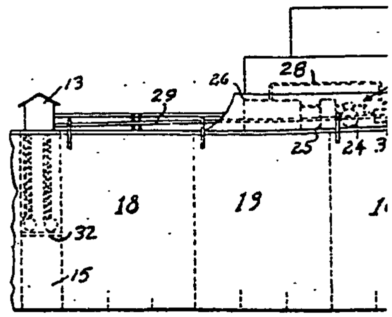


Fig 3



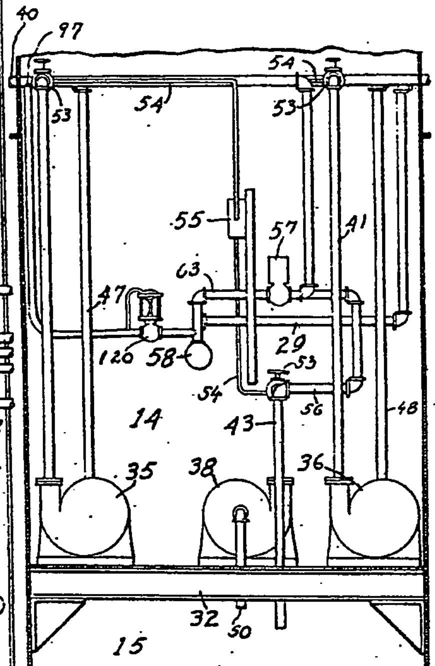
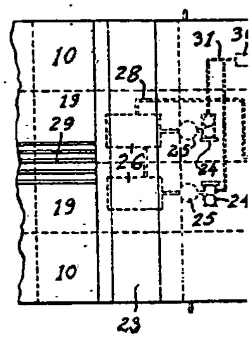


Fig 4.



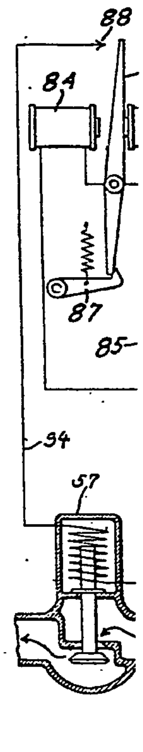


Fig 6

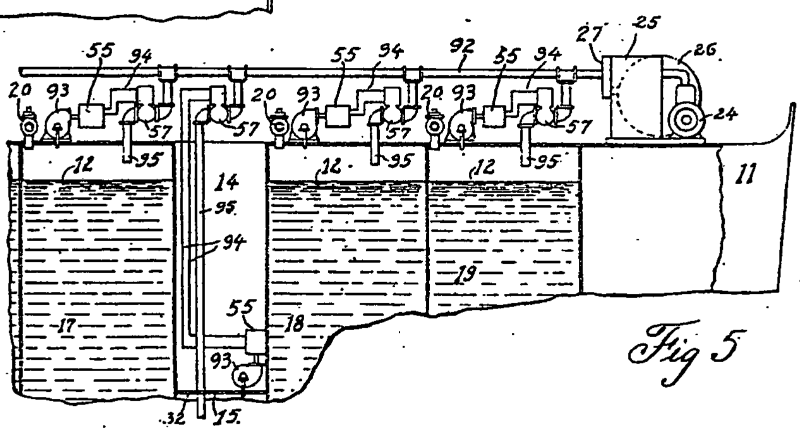


Fig 5

1 SHEET

Fig 1

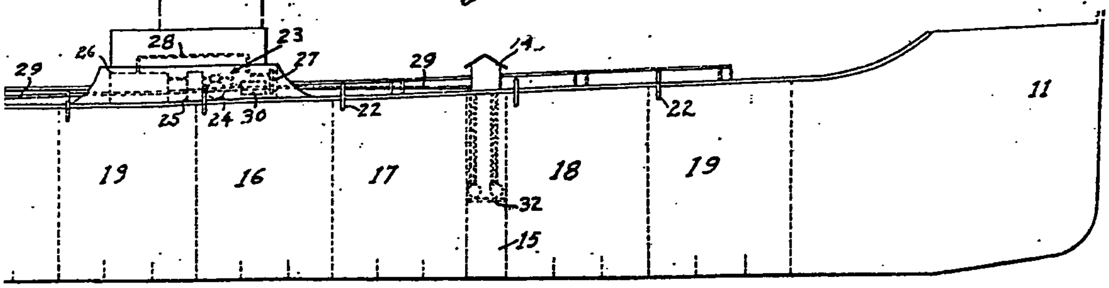
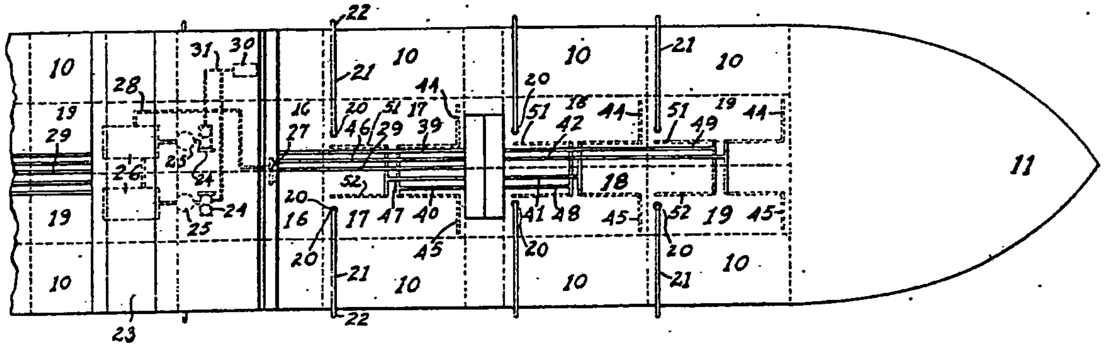
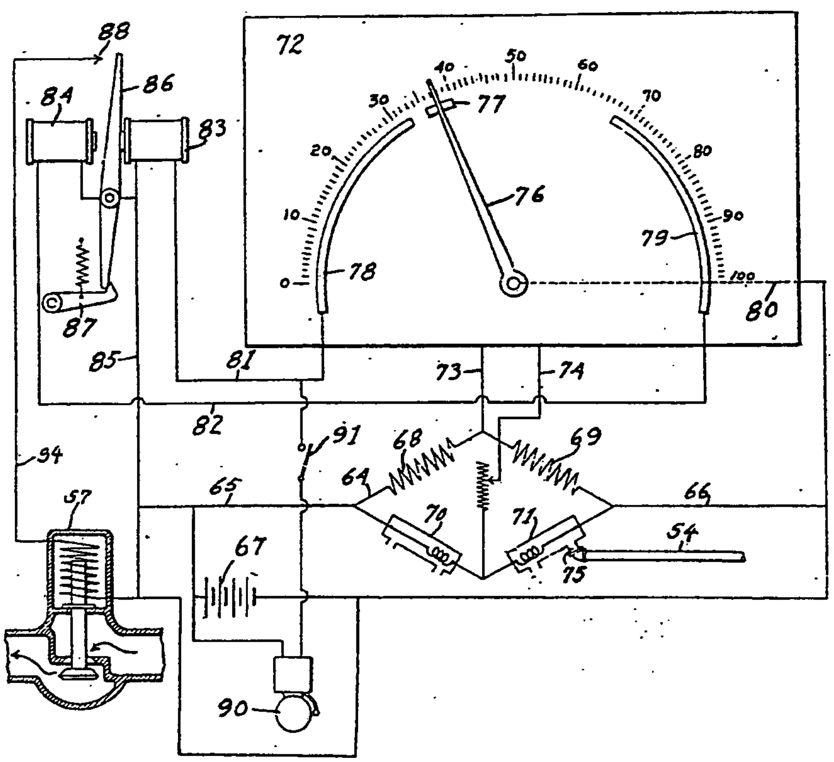


Fig 2



5



ig 6

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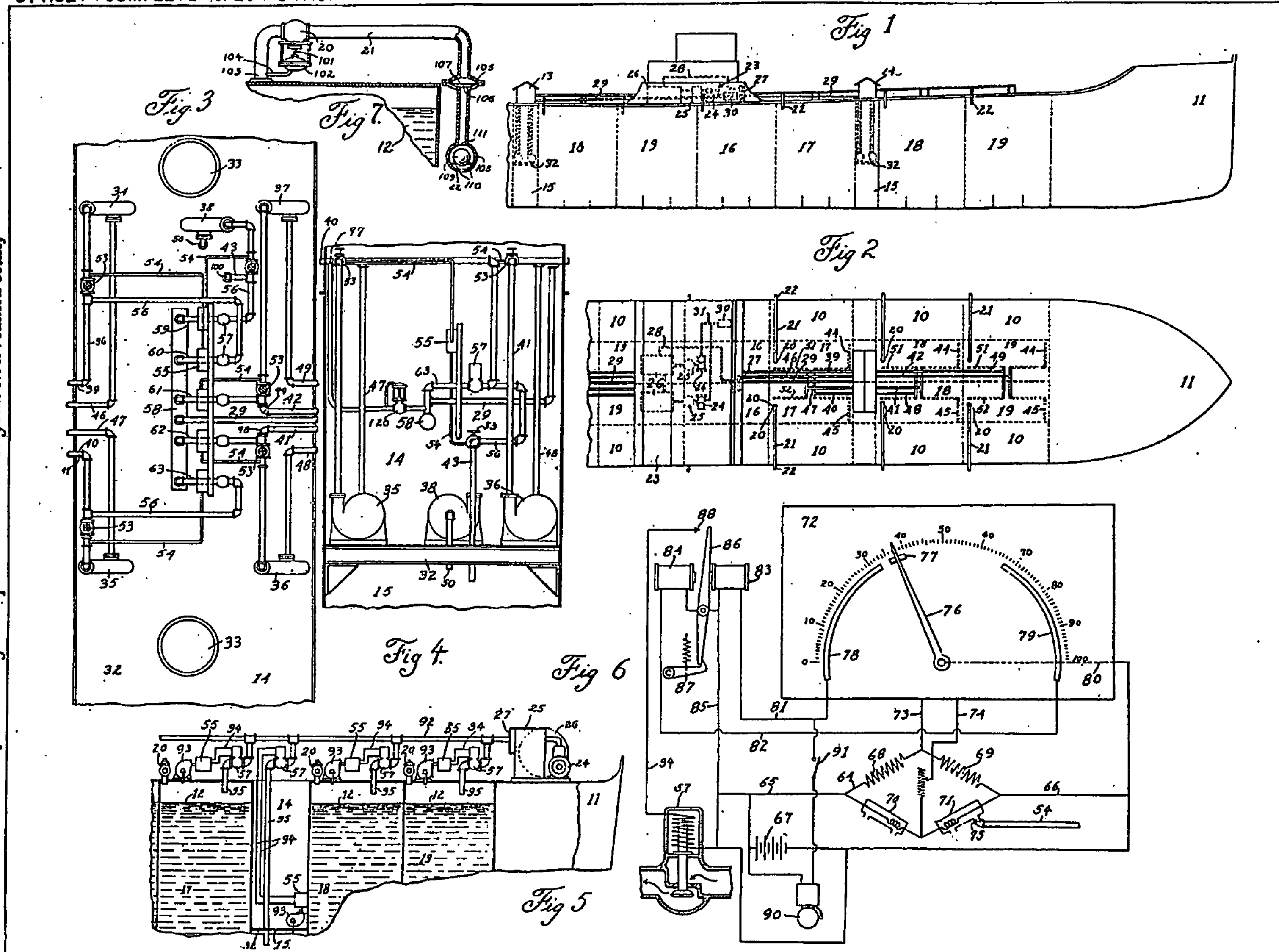

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